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GEOLOGICAL SURVEY

J. B. HOEING, State Geologist.

In Co-operation with

UNITED STATES GEOLOGICAL SURVEY
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GEOLOGY OF THE SHAWNEETOWN QUADRANGLE IN KENTUCKY

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Geology of the Kentucky Part of the Shawneetown Quadrangle.

By WALLACE LEE.

LETTER OF TRANSMITTAL

To His Excellency, A. O. Stanley,
Governor of Kentucky.

Sir:—I transmit herewith a report on the geology of that portion of the Shawneetown Quadrangle which lies within the State of Kentucky.

This report is the result of co-operative work between the Kentucky Geological Survey and the United States Geological Survey, each department paying one-half of the expense of the work.

Respectfully,
J. B. Hoeing,
State Geologist.

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INTRODUCTION

The area treated in this report lies in the western part of Union County and comprises the irregularly shaped eastern half of the Shawneetown quadrangle. It includes the mouth of Tradewater River and extends northward to a point within 3 miles of the junction of Wabash and Ohio rivers. The eastern boundary of the area passes through the western outskirts of the town of Sturgis, just east of the village of Grove Center and about 3 miles west of Uniontown. Ohio River, flowing in a wide meander from north to south, bounds the area on the west. Within the area from south to north are the villages of Caseyville, Grangertown, Dekoven, Henshaw, Grove Center and Spring Grove.

The southern part of this area was almost the first examined by D. D. Owen during the first Geological Survey of Kentucky, 1854-1858. Owen studied the outcrops in the vicinity of Dekoven and Caseyville and the work was so well done at that early date that little has been added to the stratigraphic knowledge of the coal bearing part of the section since that time even by extensive drilling, except in the details of the section and the recognition of the lenticular character of some of the lower coals and intervening beds. In 1909, L. C. Glenn,* over fifty years after the first survey, made a reconnaissance examination and report on the coals of the Tradewater River region and brought out many interesting details concerning the lower coals and added considerable knowledge concerning the beds above the Herrin coal, known in Kentucky as No. 11 since the days of Owen. He also made tentative correlations of some of the isolated coals in the upper part of the section, which so far as they lie within this area are confirmed by the more recent work.

*Glenn, L. C. Coals of the Tradewater River region, Bull. 17, Kentucky Geological Survey, 1912.

The northern part of the area has never received much attention and beyond the fact that the coals were thought to be deep and that the area is crossed by the Rough Creek fault zone, little has been known regarding it. This is in part due to the fact that outcrops are comparatively few and indeterminate, almost the entire area being covered by loess deposits varying from 15 to 40 feet thick, and to the fact that practically no drilling has been done in this part of the county. Information is still scanty in the area, but it seems possible from a detailed study of sections in adjoining areas, from consideration of the few outcrops found, from information gleaned from shallow water well borings, and from critical consideration of physiographic features, to gain a fair idea of the attitude of the beds in this little known part of the western Kentucky coal field.

Credit is due to Glenn for the recognition of some 600 feet of "Upper Coal Measures" deposits which lie above those observed by Owen. This part of the section worked out from outcrops in Webster and eastern Union counties has been confirmed by a hole bored near Henshaw which establishes the horizon of rocks outcropping in the synclinal area extending southeast from Henshaw.

As has been stated, outcrops are few and isolated, but some at least are distinctly identifiable and by consideration of observed dips in identifiable exposures, proximity and geographic location of others, most of the outcrops have been identified with considerable confidence.

A great deal of information derived from water wells drilled within the area has been lost, due to inattention of drillers or lack of interest on the part of the farmers. Even in cases where thick coals have been noticed, little note has been made of the depth. Some information, however, has been secured, chiefly from Mr. J. A. Detraz, who has drilled a number of wells in the area, and some additional information has been acquired from the owners of drilled wells. The information, however, especially in regard to character of material and statements of the thickness of coal, has been received with considerable caution, and is at best scanty and inaccurate. Table No. 1 gives, in tabulated form, the data secured in this way.

In certain areas, particularly north of Grove Center and south of the Rough Creek fault, no information from well logs or outcrops is available and the structure of the area as tentatively shown is based on the interpretation of physiographic forms.

CHAPTER I.—STRATIGRAPHY

CARBONIFEROUS SYSTEM

MISSISSIPPIAN SERIES

The rocks of Mississippian age are not known to outcrop in this area but it is possible that on the north side of Bald Knob, where the upturned edges of the deeper rocks come to the surface, the upper Mississippian rocks outcrop beneath the thick cover of loess. None of the drill holes put down in prospecting for coal have penetrated these rocks. A mile south of the mouth of Tradewater River, however, upper Chester rocks, of Mississippian age, are exposed in the river bluffs on the Kentucky shore, but they are separated from the Pennsylvanian rocks to the north by faulting.

PENNSYLVANIAN SERIES

The consolidated rocks of the area are all of Pennsylvanian age. The entire thickness of the series in Union County, Kentucky, is over 2650 feet, most of which is present in the part of the county included in this report. The base of the series, however, does not outcrop on the Kentucky side of the river within this quadrangle, but opposite Caseyville on the Illinois shore, south of the mouth of Saline River, a complete section of the basal Pennsylvanian beds resting on Chester beds, of Mississippian age, is more or less perfectly exposed. It is probable too that some of the beds at the top of the section exposed in the eastern part of the county have been eroded from the synclinal area extending southeast from Henshaw. In Illinois the Pennsylvanian series has been divided by David White* into three formations, cor-

*White, David. Paleobotanical work in Illinois in 1908, Ill. Geol. Surv., Bull. 14, p. 294, 1908.

responding approximately in age to the divisions of the Pennsylvanian in Pennsylvania. These formations have been named Pottsville, Carbondale, and McLeansboro, and they approximately correspond in age respectively to the Pottsville, Alleghany, and Conemaugh formations of Pennsylvania. The precise limits of each of these divisions in Illinois, however, is not known through lack of evidence, and as a matter of convenience in mapping, certain coal beds lying near the true points of division have been chosen to separate the formations.

POTTSVILLE GROUP

The Pottsville formation, as the Pottsville is known in central Illinois, varies in thickness from 100 to 500 feet, but the thickness increases considerably toward the south and southeast and in western Kentucky it is over 1100 feet.* The Pottsville rests unconformably on the eroded surface of the Mississippian rocks. In Hardin County, Illinois, the topmost formation of the Mississippian Chester group, the Clore limestone, has a thickness ranging from 40 feet to over 200, and this inequality of thickness, due largely to erosion, is no doubt reflected inversely in the basal deposits of the Pottsville. The top of the Pottsville is here taken as the base of the fire-clay underlying the coal bed called No. 5 by Owen but now more commonly known in Union County as No. 6, and referred to in this report as the Davis coal. As determined by David White, it occupies, approximately if not exactly, the stratigraphic position of the Murphysboro or No. 2 coal of southern Illinois, with which it is provisionally correlated.

The increased thickness of the Pottsville in the Shawneetown region, and the contrasting character of its upper and lower parts, justify its subdivision into two formations. The lower formation (Caseyville) is distinctly sandy and contains a series of massive sandstones with subordinate shale deposits and a few thin, non-persistent coal seams, while the upper formation

*This does not apply to the whole of the western coal field. The Pottsville has its greatest thickness in Union and Webster and possibly in Henderson counties. South, southeast and east from this section it thins again. J. B. H.

(Tradewater) contains shale and fine sandy shale beds with subordinate, for the most part, non-persistent and lenticular sandstone horizons and several more or less persistent, bifurcating coal beds which are locally of economic value.

CASEYVILLE SANDSTONE

The name Caseyville was applied by Owen to the conglomeratic sandstones outcropping at Caseyville, but since the sandy basal part of the coal measures was usually referred to as the "Millstone grit," or merely as "the conglomerate," it seems that the use of this term, as well as of "Battery Rock," which was applied to similar conglomerate on the Illinois side of the river, was geographic rather than formational. The term Caseyville conglomerate was revived by Glenn in a formational sense, but since the term conglomerate is to a certain extent a misnomer, and because the rocks to which Glenn applied the name Caseyville are a lithologic subdivision of the more inclusive Pottsville, they are here referred to as the Caseyville sandstone. The formation includes all the beds from the top of the sparsely pebbly sandstone exposed at Caseyville to the base of the Pennsylvanian series.

The following section was measured from outcrops on the Illinois shore of the Ohio River between the mouth of the Saline River and Gentry's landing below Battery Rock:

Descending Section of the Caseyville Sandstone.

	Feet
Massive, coarse bedded conglomerate, pebbles subordinate	55
Conglomerate, pebbles very abundant	25
Clay shale, blue gray to dark, increasingly argillaceous below	5+
Talus. Includes a thin coal near Caseyville	20
Sandstone, loose, dirty, ragged bedding	25
Clay shale, blue	7
Sandy shale and shaly sand	17
Clay shale	30
Clay shale with limestone bands 1 to 4 inches thick, 2 to 3 feet apart	26
Limy shale, blue, with four bands of dense limestone resembling iron stone, 2 to 4 inches thick	8
Limestone, dense, hard, like ironstone when fresh, weathering platy and argillaceous	5
Shale, blue	13
Talus	5+
Sandstone, massive, contains coarse mica and fine black specks at base	22
Black, sandy slate	1
Slaty sand in thin sheets, dark, carbonaceous	5
Shale, black sandy	5
Not exposed	5+
Coal (Battery Rock)	2
Talus	10
Sandstone, loose, irregular in texture	2
Talus	20
Sandstone, slabby, dense, fine grained, ripple marked	20
Talus	10
Sandstone	3
Talus, probably shale	15
Shale	3
Sandstone in thin beds probably alternating with shaly sandstone	23
Talus	10
Conglomerate (exposed at Battery Rock)	65
Sandstone, dirty and slabby	5
Talus	22
Sandstone, massive	7
Slaty sand	3
Talus	12
Total	511

Top of Mississippian.

The conglomeratic character of these rocks is not so predominant in this region as was originally supposed from the prominence of the conglomeratic beds in exposures. In the section just given they aggregate only about one-third of the whole and it is therefore a misnomer to apply the term conglomerate to the beds. The grains are as a usual thing coarse and not well sized, but in most exposure pebbles are distinctly subordinate and are only locally sufficiently abundant to present the usual conception of a conglomerate. The pebbles are of crystalline quartz, usually subangular and partially rounded crystals up to a quarter of an inch in diameter, though sometimes coarser. They are usually distributed throughout the rock in a most irregular manner in swirls, nests or pockets, especially where bedding and lamination are absent, but sometimes form definite but never continuous bands where the sandstones are more or less distinctly bedded. Frequently a short distance laterally from a highly conglomeratic phase of the deposit, the pebbles are so rare that only a very careful search reveals their presence.

The conglomerate occurs in two members, one at the top of the division, exposed at Caseyville, and the other near the base, exposed conspicuously at the Battery Rock on the opposite side of the river. The intervening beds outcrop beneath the bed of the river. It is probable that between the two conglomeratic horizons just mentioned there may occur one or more conglomeratic beds of more or less local character, but none was observed in the Ohio River exposures at this point.

At Gentry's landing on the Illinois shore some 35 to 50 feet of thin bedded and impure sandstone intervenes between the base of the lower conglomerate bed and the top of the Mississippian, but in many exposures in Hardin County, Illinois, the conglomerate rests directly on the Mississippian beds without the basal deposit which in this case may represent the debris from Chester sandstones accumulated in the low places of the eroded surface.

The lower conglomerate bed has a thickness of 60 feet at Battery Rock and presents the characteristics of irregularity in texture and composition mentioned.

The coal formerly worked at Battery Rock opposite Caseyville on the Illinois shore, lies 120 feet above the top of the lower conglomerate member, the intervening interval being composed of thin bedded, slaty and micaceous sandstones with subordinate thin, massive sandstone members interbedded with thin argillaceous layers. The identity of this coal was much discussed by the early geologists and Leo Lesquereux, on the basis of the plant fossils found in the roof shales, erroneously concluded that it was the equivalent of the Bell coal and above the conglomerate,* though he recognized a discordance in the lithologic character of the roof shales. His opinion seems to have been maintained by Kentucky geologists until the present, Glenn reaffirming the equivalency in 1912.†

Above the Battery Rock coal are thirty or forty feet of sandstone and shales, and above this 84 feet of blue clay shale which is interstratified in the lower half with dense sheets, 1 to 4 inches thick, of smooth, fine-grained limestone somewhat resembling iron stone. One of these bands, some 10 feet above the base, attains a thickness of 5 feet. At an exposure in a gully half a mile below Sellers' Landing it displays all the characters of the thinner bands, but at another outcrop a few hundred feet farther north, where the exposure is weathered, it is a soft, yellow gray, sheeted, argillaceous and fossiliferous limestone. The shales in the lower part are calcareous. This group of beds, including the limestone, is exposed at the outcrop on the river bank at Shawneetown, Illinois, at low water.

The vertical interval from the top of this shale member to the base of the upper bed of conglomerate, a distance of 75 feet, is occupied with thin, irregularly deposited beds of sandstone, sandy shales and shale which are nowhere well exposed. In Kentucky, in an old quarry at the foot of the bluffs opposite the tipple of the West Kentucky Coal Company, a 4-inch bed of coal is seen about 25 feet below the base of the conglomerate. What

*Ky. Geol. Surv., Vol. 3, 1856-1857, Leo Lesquereux, p. 531.
†Ky. Geol. Surv., Bull. 17, coals of the Tradewater River region, 1912, L. C. Glenn, p. 20.

is probably the same coal bed has been opened by a prospect pit 15 feet below the base of the conglomerate on the north side of the Tradewater on the first bluff above its mouth. It is probably this coal which was penetrated in the well at the blacksmith shop and in the Nelson well at Mulfordtown. The latter, starting near the top of the Caseyville sandstone, penetrated 5 inches of coal at 75 feet. This coal was not observed in the exposures on the Illinois shore, but on the road southwest from Sellers' Landing its presence is suggested by several springs 10 to 20 feet below the upper conglomerate, thought to issue on the impervious fire-clay which underlies the coal streak. The upper conglomeratic member so conspicuously exposed at Caseyville and southward to the mouth of the Tradewater is 60 to 70 feet thick. It is in places sparsely conglomeratic, but the sand grains are uniformly ill sorted and usually coarse. On the Illinois shore at Sellers' Landing it seems to be somewhat thicker. At Caseyville and on the Tradewater the exposures are more evenly bedded than on the Illinois shore, which probably accounts for the fact that there are comparatively fewer pebbles. On the Tradewater the sandstones are strikingly cross-bedded, the inclination being throughout, from top to bottom, toward the southwest.

TRADEWATER FORMATION

The Tradewater formation of this report is identical with the Tradewater formation proposed by Glenn. It constitutes the upper formation of the Pottsville group and comprises those beds between the top of the Caseyville sandstone and the base of the underclay of the coal termed No. 5 by Owen but now more generally known in western Kentucky as the No. 6 or Davis coal. The beds of this formation have been penetrated frequently by drill holes to the depth of the Bell coal, and excellent exposures of the greater part of the formation are to be seen in the ravines and bluffs between Caseyville and Dekoven. This locality presents the type section for these rocks and has been frequently studied. Both Owen and Glenn have published sections based on studies of the outcrops. The beds are so variable in character, how-

ever, that sections made by two persons would not and do not agree except in the more conspicuous features.

The following section, based upon drill holes between Sturgis and Caseyville and outcrops at the latter locality, gives perhaps a better idea of the nature of the beds than can be gained from the outcrops. One hundred and three feet at the top of this section are taken from a log near Sturgis. The section from 103 feet down to the Bell coal, a vertical distance of 433 feet, is taken from a log midway between Sturgis and Caseyville, while the section below the Bell coal is made up from outcrops near Caseyville.

Section of Tradewater Formation.

	Feet	Inches
Gray shale	22	
Gray slate	10	
Black slate	11	
Coal		6
Gray shale	11	
Limestone	2	
Black slate	2	
Coal		4
Gray shale	13	
Yellow shale	4	
Gray shale	11	
Sandstone (Curlew sandstone of Owen)	6	
Black slate	4	
Coal		3
Fire-clay	1	
Sandstone	5	3
Dark slate	2	
Fire-clay	1	
Shale, mixed with fire clay	7	
Dark shale (horizon of Curlew limestone of Owen)	38	
Dark sandy shale	6	4
Dark shale	14	
Variegated shale	1	
Dark sandy shale	5	
Coal	0	10
Shale, mixed with soapstone	5	
Dark shale	6	2
Sandstone	7	
Shale, mixed with fire clay	2	
Dark slate	2	
Sandy shale	4	

	Feet	Inches
Dark, sandy slate	5	
Sandstone and shale, mixed	22	
Bastard fire clay	1	
Coal	0	8
Shale, mixed with soapstone	4	
Dark slate	15	
Gray, sandy shale	16	
Dark slate	6	4
Coal, Smith (?)	1	10
Coal and slate mixed	1	
Shale, mixed with soapstone	5	
Coal	0	5
Sandstone	5	
Gray shale	0	7
Dark shale mixed with soapstone	10	
Sandy shale	5	
Sandstone	38	6
Dark slate	1	6
Coal	1	2
Shale, mixed with fire clay	9	10
Dark slate — Coal Ice House (?)	2	
Sandy slate	10	
Coal and bony coal	1	6
Shale	1	
Shale, mixed with fire clay	1	6
Sandstone (Finnie sandstone of Owen)	44	
Sandy shale	4	
Dark slate	9	
Sandy shale	3	
Sandstone	10	
Dark slate	3	
Shale, mixed with fire clay	4	
Sandy shale	8	
Dark blue, shaly slate	70	
Coal, Bell	3	6
Shale, mixed with fire clay	2	6
Shales, in part sandy	20	
Clay shale, bluish	15	
Clay shale, sandy, with iron stone	6	
Clay shale, black, slaty	4	
Coal, 1A of Owen		8
Fire clay	1	
Shale and sandy shale	16	
Total	594	2

As has been stated, the section just given from borings is more representative of the formation as a whole than is the section given by Owen and Glenn from the outcrops seen along the river bluffs between Caseyville and Dekoven. The thickness demonstrated by the logs from the top of the Bell coal up to the base of the Davis or No. 6 coal varies from 515 to 540 feet in different localities, but as given by Owen in his composite bluff section this interval is given as only 400 feet, and by Glenn as 450. Instead of containing three well defined and continuous coal beds denominated No. 2, Ice House and Curlew coals by Owen, this interval is in reality composed of a very irregular sequence of deposits containing an extremely variable number of thin coals which are found to approach workable thickness only locally. The beds, however, are in some cases grouped in zones and in some cases appear to be bifurcated parts of the same bed. None of the three coals just mentioned is positively identifiable at any point in the bluff exposures except at the type locality, and there are at various points thin coal seams which seem to be intercalated above and below the horizons of the coals described and named by Owen.

The interval from the top of the conglomerate exposed at Caseyville to the Bell coal is known only by the outcrops in the vicinity of Caseyville and near the old Bell mines south of the Tradewater. It shows the same irregularity as the part of the section above the Bell coal. On the road below the school house at Caseyville an 8-inch coal outcrops 16 feet above the conglomerate. What is believed to be the same coal was observed at several other points in the vicinity of Caseyville, about 1 mile south of Caseyville above the bluffs, and again in Caney Creek above the old Bell mines south of Tradewater River, but at no point except the former could the interval to the top of the Caseyville sandstone be measured. This coal was referred to by the early geologists as coal 1A, since it was considered on rather inadequate grounds, to be a lower bench of the No. 1 or Bell coal. It is separated from the Bell coal by beds of sandy shale varying considerably in thickness, if, as is believed, the exposures of the lower coal just mentioned are all of the same bed.

On the road south from Caseyville the interval does not exceed 30 feet, while at Barnaby's mine, on the southern edge of the area it is not less than 75 feet. The Bell coal approaches 4 feet in thickness at the latter point, while northward at Caseyville and Mulfordtown it is said to be as thin as 26 inches. It is therefore thickest where the interval to the underlying thin coal is greatest.

The Bell coal is the only bed in the formation which is sufficiently distinct and persistent to be identifiable with confidence throughout the area of its outcrop. At its base is a layer of 6 to 10 inches of brittle rash. It is overlain by a micaceous, finely sandy shale of rather striking appearance which was called "gray metal" by Owen. This shale is thinly bedded and has on the partings closely spaced, somewhat elongated twig-like concretionary aggregations, probably calcareous, which give the surface the appearance of having been littered with broken bits of stems or small branches. Whatever the origin, this peculiar shale, although not unique, is a useful criterion in identifying the Bell coal. The thickness of this shale varies, however, being only a few feet thick on the Tradewater to 15 to 20 feet or more locally at Caseyville and Mulfordtown.

Above the Bell coal conditions of sedimentation were extremely variable. It is true that in the outcrops along the river bluffs and in the ravines in the southern part of the area there are several coals which approach a workable thickness, and two sandstone members which are somewhat persistent, but none of these maintains its individuality for more than a short distance, and they are somewhat doubtfully identified in the several drill holes 2 to 4 miles distant. So marked is the variation in parts of the section that it is scarcely possible to correlate the beds in two sections secured in adjacent ravines east of Caseyville less than ½ mile apart, although the exposures at both localities are unusually good. One of the ravines parallels the road from Caseyville to Sturgis. The other is the next ravine to the north, separated from the first by a small ridge. In both of these ravines a thin coal, 1 or 2 inches thick, is present 45 feet above the top of the Bell coal. Thirty-two feet above this, in the ravine to the north, there is a prospect pit showing coal

several inches thick on the dump. In the road ravine, however, this horizon is occupied by 20 feet of sandstone. In the talus at its base a slab of pebbly conglomerate was observed, and although diligent search was made in the sandstone above the top of the Caseyville sandstone throughout the area, this is the only known occurrence of quartz pebbles above that horizon. Twenty feet above the coal just mentioned, in the northern ravine, 10 to 15 feet of massive sandstone outcrops and this is believed to be the same sandstone as that occurring in the road ravine, although it is distinctly higher, the inference being that the sandstones accumulated on an eroded surface and that the coal of the northern ravine was eroded during the interval. Thirty feet above the massive sandstone in the road ravine, and 125 feet above the Bell coal, 2 feet of shaly coal is exposed underlain by 1 foot of coaly black slate with plant remains and a few shells, probably coal No. 2 of Owen's section. This bed in the other ravine is represented only by 3 inches of dirty coal overlain and underlain by white micaceous shale. None of the other distinctive overlying beds are exposed in both places, but the discordant character of the beds is clearly indicated.

At Mulfordtown 3 feet of fossiliferous sandstone, with impressions of roots and stems, outcrops 30 to 35 feet above the Bell coal, but 500 feet south, 30 feet of similar sandstone appears at a slightly higher level. These beds may either represent lateral variations of the same lense or else distinctly separate lenses. East of Caseyville this bed seems to be absent or is represented by a thin layer only.

At the old Casey mines on the Tradewater 40 feet of sandstone occurs 40 feet above the Bell coal, while at the Bell mines 15 feet of sandstone is present 50 feet above the coal. Between the upper sandstone and the Bell coal there is often a thin, lenticular sandstone bed, 6 feet thick at the Casey mines and 12 to 20 feet thick at the Bell mines, but these are only local deposits.

Just north of Mulfordtown a bold and seemingly persistent sandstone horizon caps the bluffs, its base being 130 feet above the Bell coal. This member was referred to by Owen as the Finnie sandstone, but like most of

the other members of the Tradewater formation it has not proved to be a very persistent member. Casual inspection of this sandstone gives a false impression of its character. It appears from below to be a massive bed 50 feet thick, but as a matter of fact only the upper 15 or 20 feet is of this nature. The lower part is composed of a series of shales and sandy shales and lenticular sandstones, the latter rarely more than 5 feet thick, the former varying sharply in thickness from a few inches to 4 or 5 feet. The basal 5 or 10 feet contains in places coaly streaks and above the coaly sand is a thin bed of conglomerate, the pebbles of which are composed of greenish shale. The sandstone is continuous along the top of the bluff for a distance of nearly 2 miles, but in the ravine just north of Mulfordtown less than ½ mile from its maximum development, it is represented by only 10 feet of massive sandstone, and in the ravine sections east of Caseyville it is apparently not represented at all. In the drill holes a sandstone is usually reported near this horizon, but it varies greatly in thickness and in its distance above the Bell coal. The Finnie sandstone of Owen probably represents the filling of an erosion channel. A thin and no doubt very local coal streak was noted 18 feet below the south end of the bluff outcrop north of Mulfordtown.

At the northern end of the exposure of the sandstone to which Owen applied the name Finnie, the northeastward dip carries the bed beneath the flood plain of a small tributary to the Ohio. Here the coal described by Owen as the Ice House coal can still be seen at the type locality. It lies apparently about 20 feet above the top of the sandstone at this point. Only the top of the bed can be seen at present, the roof having caved to some extent. The top of the coal appears to have suffered little from exposure in the sheltered entry and is still black and lustrous. It is overlain by 4 to 6 inches of soft black slate, above which is an interrupted band of iron stone 4 to 6 inches thick. This is followed by 8 feet of gray, micaceous clay shale with occasional lenses and balls of iron stone, followed by 2 feet of fine grained sandstone which, by sustaining the natural arch, has served to prevent complete closing of the entry.

The Ice House coal was reported by Owen to be 2 feet 6 inches thick at this point, but in the ravine at Mulfordtown it shows as only a faint smut and in the northern of the two Caseyville sections what is believed to be the equivalent of the Ice House coal appears as two thin sheets 2 and 3 inches thick, separated by 5 feet of soft, gray, micaceous clay containing a number of very poorly preserved plant fossils.

In the drill holes nearest the outcrops mentioned, the place of this coal seems to be occupied by a single coal from 2 to 16 inches thick, but toward Sturgis and on the south side of the Tradewater a group of coals is present at this horizon. Within a vertical distance of 30 feet there are present in one well four distinct beds, which may be either bifurcated parts of the main coal or separately formed coal lenses. While, therefore, there is little to identify this horizon *per se*, its horizon can often be determined approximately by the intervals if a suitable datum is present in the log either above or below.

In the Mulfordtown hollow there is a 14-inch bed of coal 50 feet above the coal smut believed to represent the Ice House coal. This coal is of good quality and though it has been exposed for several years in a small drain it is remarkably fresh. It is underlain by impure fire-clay and micaceous shale, and is immediately overlain by 10 feet of slabby sandstone. It is not known to outcrop at any other locality, but a coal which varies in thickness from 1 inch to over 2 feet is reported at this horizon in several of the logs drilled in the area and it may be the equivalent of the coal opened at the Smith mine south of the Tradewater. Owen observed a thin coal at this horizon but did not give it a name.

Borings in the Tradewater area show several local thin beds of coal in the 75-foot interval above the coal just described, one of which, about 100 feet above the Ice House coal horizon, attains a thickness of 30 inches south of the Tradewater. It is usually not reported, however, and is probably not present in most of the area. The Curlew coal, described by Owen as the No. 4 coal, is probably a bed of this character. It was observed by the writer as a coal smut below Owen's Curlew sandstone,

but it is not possible to differentiate it in the logs from any of several sporadic coal seams which appear at irregular intervals in this part of the section.

The interval from the Ice House coal to the top of the formation is the most confusing part of the section. As given by Owen in his section it is 250 feet and by Glenn as 275, and this is the apparent interval southwest of Dekoven. The absence of sharp datum planes, however, and the confusion of thin coals and sandstone lenses, combined with the poor exposures and somewhat variable dip of the beds, makes a careful measurement very difficult. The thickness, as given in the logs of wells, is 325 feet for this interval, and disregarding the possibility of convergence this is probably the correct thickness.

In the outcrops near Dekoven the base of Owen's Curlew sandstone, so far as can be determined from the outcrops, is 175 feet above the Ice House coal. It is a massive, medium grained, and generally cross-bedded sandstone 20 to 40 feet thick in its outcrops along the crest of Indian Hill. To the east it is reported to be thin or absent in some of the most detailed logs, though perhaps present in others. Glenn reports it to be traceable southeastward to Charleston and Beulah, but it is not a conspicuous horizon between Dekoven and Tradewater River nor does it affect the topography, as is usually the case in this area where heavy sandstone beds outcrop. Twenty-five feet below the base of this sandstone member on Indian Hill are several weathered and incomplete exposures of Owen's Curlew limestone. The limestone is probably over 3 feet thick, but it is not a homogeneous unit, being composed of several lithologically different layers. One of these is argillaceous, another strongly crinoidal, and small bits of porous chert found in the detritus at this horizon suggest that it is in part siliceous. Thin bands of coal were seen both above and below the limestone, the upper being no doubt the equivalent of Owen's Curlew or No. 4 coal, which has already been mentioned. On the footpath between Mulfordtown and Dekoven, on the eastern slope descending toward Dekoven, a thin 3-inch seam of coal is to be seen which may be the equivalent of one of these.

The Indian Hill locality furnishes the only known outcrops of this limestone, but on the isolated hill due south from the Dekoven station a single small bowlder and a few pebbles of limestone were found 55 feet below the base of Owen's Curlew sandstone. The drill logs, however, fail to show a persistent limestone at this horizon, only one of the logs reporting the presence of a limestone. It is not improbable, therefore, that the bed is of extremely local development, like so many of the beds of the formation.

There are no exposures of the greater part of the interval between Owen's Curlew sandstone and the top of the formation, a vertical distance of about 130 feet. In the most detailed logs this interval includes from one to three limestone beds 1 to 3 feet thick, but these, like Owen's Curlew limestone, are thought to be local. The beds of this part of the section consist chiefly of sandy shales and shales with five or less thin coal seams, none of which has been reported to exceed 15 inches, and most of which are generally less than a foot in thickness. Thirty or 40 feet of sandy and micaceous shales are to be seen at the top of the formation near the station at Dekoven, and a similar exposure occurs at the Davis mine.

South of Sturgis three beds of coal in this formation in addition to the Bell coal, locally approach workable thickness. The lowest of these is probably equivalent in age to Owen's Ice House coal. This coal was opened at the Hillman shaft and was thought to be the Bell coal, but it is evident from the relation of the top of the shaft to the outcrops of the Davis coal, from its shallow depth below the surface, and from comparison of the log of the shaft with other logs in the vicinity, that the Bell coal is to be found 175 to 200 feet deeper. It has a reported thickness of from 54 to 61 inches at and near the old Hillman shaft, but with a local parting from 7 feet 6 inches to 3 feet thick in the middle. A boring less than ½ mile to the south, however, is said to have penetrated 4 feet 10 inches of solid coal without partings.

The coal mentioned as occurring 50 feet above the Ice House coal in the Mulfordtown ravine appears to be the equivalent of the coal worked at the old Smith opening, now abandoned, where it is said to have been 3 feet 6 inches thick. In the hole drilled at the Rutherford school this coal is said to be 32 inches thick, but in the Hillman shaft log the corresponding bed is reported to be only 18 inches thick.

A third bed, 50 feet higher, was found south of Grangertown to be 24 inches and 30 inches thick in two holes, but it thins to a few inches at the Rutherford school. It will be seen, therefore, that while some of the beds intervening between the Bell coal and the Davis coal may be of workable thickness at some places, it is desirable to drill the area very carefully before undertakng their exploitation.

CARBONDALE FORMATION

The interval from the Davis coal, called No. 5 by Owen but now known in western Kentucky as No. 6, up to the base of the Anvil Rock sandstone member was divided by Glenn into two formations at the horizon of the Springfield or No. 9 coal, and these have been mapped separately heretofore by the Kentucky Survey. The only advantage of this division, however, is that it shows the outcrop of the No. 9 coal, economically the most important in the western Kentucky region, but the two formations are both thin and there is no paleontologic nor stratigraphic break at this point, so that it seems better to include these beds in one formation and to show the outcrop line and structure contours of this coal instead of mapping a separate formation. The beds from the base of the fire-clay underlying the 4-foot coal to the top of the Herrin or No. 11 coal have been called Carbondale in Illinois and correspond closely in their limits to the Alleghany formation of Pennsylvania. The series is, however, apparently continuous without notable interruption from the Davis coal up to the base of the Anvil Rock sandstone, at which horizon a rather conspicuous break occurs. It would perhaps be more logical to include in the Carbondale formation the rocks between the Herrin coal and the unconformity, if it were not for the fact that the outcrop of this coal has a distinct economic value and because the line of unconformity is rarely so conspicuous as to make it possible to map the more natural

division. The top of the Herrin coal was therefor chosen as the upper limit of the formation, and as the interval between the coal and the unconformity is rarely more than 30 feet, the difference in the actual outcrop line of the two surfaces is small.

This formation contains the four coal beds of greatest economic importance in the area, the Herrin or No. 11, the Springfield or No. 9, and the Dekoven and Davis coals, Nos. 7 and 6 respectively. With the beginning of the Carbondale, conditions of sedimentation became much more uniform. The coal beds of this formation are distinctly traceable for many miles and most of them display a distinctness of character in themselves or in the associated beds, which usually permits their identification, so that the coal beds themselves serve as the most important datum planes in studying the stratigraphy of the region.

The Davis coal, which lies at the base of the formation, has a uniform thickness throughout the Tradewater region and averages so nearly 4 feet that it was called the "4-foot coal" by Owen. Beyond the numerical appellations which have been applied to it, No. 5 of Owen and No. 6 of the present usage, it has never received until the present any other name in Kentucky. It occupies the same or very nearly the same stratigraphic position as the Murphysboro or No. 2 coal in Illinois. The fire-clay at its base has not been observed, but thicknesses reported from drill holes show it to be less than 30 inches thick. The roof is a tough black slate 6 to 12 inches thick, but between the slate and the coal there is an interrupted band of hard, black, highly pyritiferous, usually somewhat calcareous clay. The lime constituent occurs in small marine shells which are present in great abundance and variety. The pyrite has to a very considerable extent replaced the lime and the shells are often entirely transformed into beautiful and perfect marcasite casts of the original shells. The oxidation of the pyrite takes place very rapidly, and after only a few weeks of exposure the fossils are entirely destroyed and the material transformed into a soft mass of flaky brown to black shale.

At Dekoven the interval from this coal to the next higher is only 28 feet, but drill holes east of Sturgis show

the interval to be 50 and 55 feet at that point. This coal was called the 3-foot coal or No. 6 by Owen, but it is now referred to locally as No. 7. It is underlain by a thin but variable thickness of fire-clay, but the interval between this coal and the Davis coal is occupied chiefly by shale. The coal is brittle and of excellent quality. Its thickness, however, is more variable than that of the Davis coal. At the old mine at Dekoven station, the entry of which is still open, the thickness is 44 inches, but farther eastward its thickness is reported by drill holes to be 2 feet 4 inches and 3 feet at points less than 1 mile apart. The roof of this coal at Dekoven is micaceous shale, more or less carbonaceous due to an admixture of what appear to be macerated leaf fragments interbedded with a thin sheet of bone and laminae of coaly material. This bed is not now open to examination at any other point in the district.

The rocks above the Dekoven coal are well shown on the hill near the station at Dekoven, where 75 feet of the section is exposed. A thin coal reported in the two holes drilled near Sturgis at 45 to 50 feet above the Dekoven coal is not exposed in this hill and is no doubt only a very local stratum, though Owen considered it persistent and gave it the designating numeral No. 7. In the present and local usage of the numerals this bed has been omitted, so that in counting downward from the No. 9 coal, No. 6 and No. 5 of Owen have become No. 7 and No. 6 respectively. The interval below it in the drill holes and in the section at Dekoven is occupied by shale with a sandstone member in the middle part of varying thickness. The interval from the No. 7 coal of Owen to that called the Well or No. 8 coal by Owen is not susceptible of measurement in the outcrops, the exposures of this part of the section being very poor. In the drill holes at Sturgis the interval is 45 feet and the strata consist of shale or sandy shales with subordinate sandstone. At Dekoven the section apparently consists entirely of shales, although there are very few exposures. The Well coal was so named because, although no outcrops were known, it was not infrequently penetrated in the wells in the vicinity of Dekoven. Its outcrop is now known at the company store, but the exposure is so badly weathered

that only a little coal smut can be seen. Owen gives the thickness as 2 feet 6 inches, but in the drill holes at Sturgis it is reported as 3 feet and 3 feet 1 inch, but this is no doubt an unusual thickness.

Exposures of the interval from the Well coal to the base of the Mulford coal are no better than below the Well coal. The outcrops of this part of the section almost universally occur beneath the flood plains of valleys, and the beds probably consist chiefly if not entirely of soft shale. The interval is not known definitely by direct measurement at any point within the area considered.

Two miles southeast of Sturgis a drill hole shows the interval to be 105 feet. At Morganfield, Ky., the interval is only 75 feet. Owen reported the reputed discovery on the Illinois shore of a thin coal 50 to 60 feet below the Mulford coal, but it was not an acknowledged bed and he did not give it either name or number. A coal in a similar position in the drill holes at Sturgis, in one of which it is said to be 2 feet 4 inches thick, is 26 feet above the Well coal. In Owen's first published section his Well coal is said to be at the horizon of this upper coal, while in his last section it appears at the horizon of the lower, which is taken to be the one intended to bear the name. Since, however, the exposures of this horizon are inadequate it appears likely that he at times confused these coals, and it might be desirable to refer to them respectively as the upper and lower Well coals.

The Springfield coal, or as termed by Owen No. 9, is the thickest, most uniform and most persistent coal in western Kentucky, and the chief commercial coal in this part of the Tradewater region. The roof is hard black slate 4 to 8 feet thick with so-called niggerheads, oblate spheroidal calcareous concretions, which sometimes attain a diameter of 4 feet and a thickness of 2 feet or more. The floor is fire-clay, which locally is 2 feet thick.

The interval between the Springfield coal and the Briar Hill coal, which is the next higher, is fairly uniform. In the vicinity of Sturgis the average interval is 75 feet, with a fluctuation of 2 or 3 feet on either side, though northwest of Dekoven the interval seems to be less, and westward in Illinois it diminishes and the bed finally disappears. Eastward the interval thickens.

The Briar Hill is a thin coal called No. 10 by Owen, but now known at Dekoven, where it is mined in country banks, by the term given above, the first mine on this bed being situated near a conspicuous briar patch on the hill north of the Sturgis road in the environs of Dekoven. The bed is sometimes, as at Dekoven, as thick as 40 inches, but is as a rule less than 30 inches. Drill holes southeast of Sturgis, however, show it to be over 3 feet thick at several localities.

As reported in the drill logs, the strata between the Briar Hill and Springfield coals consist of shale at the base and sandstone or sandy shale at the top, the lower shaly part being about one-third of the whole. The ratio, however, here given is a purely local one and in neighboring areas either the sand or shale may make up the greater part of the interval, though the predominance of shale below and sandstone above seems to be general. In the outcrops the sandstone reported in the drill logs is not so conspicuous as might be anticipated, the sand being soft and of medium fine grain and therefore as a usual thing not resistant.

The interval from the top of the Briar Hill coal to the base of the Herrin or No. 11 coal is quite uniform in the limited area included in this report. The interval is 37 feet, 2 miles northwest of Grangertown and about 40 feet at Dekoven. The interval thickens to the east and thins to the west, though it is irregular in Gallatin County, Ill. The beds of this interval, like that below the Briar Hill, consist of shale and sandstone, but are much more heterogeneous in character, the beds being thinner and locally interbedded with black shale and limestone. The limestones reported in the logs, when present, occur only a short distance below the Herrin coal and are probably in part only limy shale, in one instance, in a hole drilled north of Grangertown, the coal being reported as resting directly on limy shale 5 feet thick. The limestones are, however, of purely local development and do not outcrop as limestone beds, so far as known. As a usual thing the Herrin coal, like the other coals of the region, is underlain by 12 to 30 inches of fire-clay.

The Herrin coal, called by Owen No. 11, is thinner, more irregular in character and thickness in Union County, Kentucky, than in Illinois. The thickness of the bed as shown in the drill logs varies from a few inches to over 4 feet. The "blueband," a 1 to 2 inch sheet of fire-clay in the lower part of the coal, is an ever present phenomenon where the bed has not suffered erosion.

The following section is taken from two logs of wells drilled near Sturgis:

Section of the Carbondale Formation.

	Feet	Inches	
Coal, Herrin or No. 11	2	7	
Lime shale	5	8	
Sandstone	19		
Sandy shale	13	4	
Coal, Briar Hill or No. 10	2	7	
Sandstone	23	5	
Shaly sandstone	25		
Blue shale with hard bands	26		
Black slate	2	7	
Coal, Springfield or No. 9	5		
Fire clay	3		
Gray shale	22		
Sand rock	21		
Black slate	3	3	44.25
Coal, Upper Well coal	2	4	
Fire clay	4		
Gray shale	7		
Gray slate	21		83.6
Coal...	2	2	
Partin } Lower Well coal		2	
Coal...		8	
Gray shale	18		
Sand rock	10		
Gray shale	17		
Black slate	1	10	133.4
Coal, Owen's No. 7 coal		2	
Shale mixed with clay	7		
Sand rock	30		
Gray shale	7		177.6
Coal, Dekoven	2	4	
Fire clay	2		
Gray shale	20		
Sandstone	5		
Gray shale	25		
Black slate	5		232.33
Coal, Davis	4		
Fire clay	2		
Top of Tradewater formation.			
	367	6	

THE McLEANSBORO FORMATION

The McLeansboro formation includes the strata from the top of the Herrin coal to the base of the sandstone which outcrops so conspicuously from Henshaw to Dixon Springs.

The formation in Union County is known almost entirely from drill records, only parts of the section being known to outcrop. The base of the formation is exposed near Dekoven and about 100 feet at the top is known from outcrops near Henshaw, and about the same thickness near the middle is exposed on Grundy Knob. The thickness of the formation is 970 to 1000 feet. The variaton is due to some extent to the greater compacting which the formation has suffered where the shale beds preponderate than where it has a larger proportion of less compressible sandstones. Doubtless some of the variations in sedimentation are due also to irregular deposition and to slow deformation of the strata during the time they were deposited. The beds consist chiefly of shale and sandy shale, but conspicuous beds of sandstone sometimes occur in the basal 300 feet and there are conspicuously sandy horizons, apparently of a lenticular character, in other parts of the section. There is more limestone in the McLeansboro than in any other part of the Pennsylvanian section, some six or seven beds aggregating 25 to 30 feet having been reported in drill logs. The limestones, however, appear to be in part at least of local development and it is known that at least one bed conspicuous as limestone in the logs, when seen in weathered exposure appears as a yellowish gray, fossiliferous, porous, micaceous to finely sandy shale, so that except in very favorable exposures its true character might be overlooked.

The basal part of the formation includes the interval between the top of the Herrin coal and the unconformity previously mentioned. This unconformity sometimes cuts out the coal in neighboring areas, but so far as known this has not occurred in the area under consideration. The unconformity in highest parts of the uneroded section is not distinguishable in the drill logs in which the unconformable relations are chiefly recognized, but it is certain

that the relief of the surface must have at least 35 feet above the coal and probably greater.

Where the beds have not been disturbed the Herrin coal is overlain by from 2 to 10 feet of limestone separated from the coal by a parting of black slate 6 to 15 inches thick. This limestone is characterized by the presence of a small fossil known as *Girtyina ventricosa,* in size and shape not unlike a grain of wheat. Twenty-five to 35 feet above the Herrin coal is a thin coal from 11 inches to 20 inches thick, the interval between this coal and the limestone being occupied by a heterogeneous series of thin limestone, shale, and sandy shale beds. In areas in which channels were not cut during the emergence, this coal is followed by a thick bed of shale. Where erosion channels were cut, however, the beds just mentioned were removed and the renewed deposition which followed submergence filled the depressions with sandstone. This deposit in some places forms a massive bed 40 feet or more thick. It is known as the Anvil Rock sandstone member from a conspicuous isolated sandstone mass known as the Anvil Rock, on the railroad 1½ miles northwest of Dekoven. Fifty-nine feet of massive bedded sandstone is exposed at this point. The sandstone is coarse to medium grained and gray to slightly brown in color. The grains are angular and in part at least not well sized, with fresh muscovite flakes and a subordinate amount of gray kaolin-like cement in certain parts. In many places it contains abundant plant remains, usually branches and stems poorly preserved by limonite. The Anvil Rock member is well developed in and about Dekoven, but toward Sturgis it is less prominent and a drill hole 2 miles north of Grangertown indicates its entire absence. Near Spring Grove it is present but it is not so conspicuous as at Dekoven. It is a conspicuous bed westward in Gallatin County, in Illinois, and in other parts of Union, but as shown by the drill records there are many localities in which it is not found.

For 200 feet immediately above the Anvil Rock sandstone the beds are predominantly shaly and their character is expressed topographically in the open valley of Cypress Creek, nearly a mile wide, bounded on the southwest by hills preserved from erosion by their capping of

the hard, resistant Anvil Rock sandstone. Toward Sturgis, where the Anvil Rock was not deposited, the hills so prominent near Dekoven become lower and are inconspicuous, the hills at Sturgis being the topographic expression of the sandstone beds between the Springfield and Herrin coals.

Within this 200-foot interval there are several thin coal beds less than a foot thick. One, 115 feet above the base of the formation, seems to have been rather widely deposited. Another, 157 feet above the base, is of only local occurrence. A third, 227 feet above the base of the formation, is like the first, present in drill holes in Gallatin County, Ill., and eastward in Kentucky.

In most of the holes drilled in Union County, Kentucky, and Gallatin County, Illinois, which penetrate this horizon a bed of limestone is present 175 to 200 feet above the base of the formation. In a few cases two limestones are present separated by 15 to 20 feet of shale, the upper of these being reported as limy shale in the hole 2½ miles north of Grangertown. While there appears to be a distinct zone of limestone at this place in the section, the evidence of the logs is not entirely conclusive that the beds are of contemporaneous origin. It is probable that more than one period of limestone deposition is represented, the accumulations having taken place at different localities in separate basins sometimes at the same time, but often only as local conditions were favorable. No doubt some of the limestones reported in the logs are merely calcareous beds and do not necessarily represent limestone horizons.

From 227 to 425 feet above the base of the formation the strata consist chiefly of shales and sandy shales, though in adjoining areas both east and west thick sandstones beds have been reported, and in one case a thin coal.

In the Union County area a thin coal occurs 425 feet above the base of the formation and 30 feet higher another thin coal underlain by 5 feet of fire-clay and overlain a short distance higher by 7 feet of limestone. This limestone is a conspicuous and valuable datum plane in this and adjoining areas, but it should be correlated with limestones in more distant areas with great caution.

This limestone whose base is 465 feet above the Herrin coal and 590 feet above the Springfield or No. 9 coal, is conspicuously exposed on the bluff on the north side of Grundy Knob and can be traced continuously northeastward to the edge of the quadrangle, near which it dips beneath the flood plain of the Ohio. On Grundy Knob the following section was measured:

Descending Section on Grundy Knob.

	Feet	Inches
Loess	35	
Sandstone, dirty, laminated	3	
Gray shale	2	
Sandstone, like above	1	
Gray shale	1	
Sandstone	3	
Talus with coal smut, perhaps two thin beds	20	
Micaceous shale	15	
Sandy shale and shaly sandstone	4	
Sandstone, hard, calcareous	1	
Micaceous shale	40	
Limestone	7	
Slate, black	3	
Coal		6
Fire clay	4	
Micaceous shale	50	
	189	6

The limestone has straight weathered joints and a rounded lumpy surface, conchoidal fracture, and a tendency to differential weathering along bedding planes. This limestone is the same bed observed above Round Pond north of Shawneetown on the Illinois shore, but is probably not the same as that outcropping on the river bank below Uniontown, which is believed to be a lower bed, perhaps equivalent to that described as occurring 175 feet above the Herrin coal.

Above the limestone just mentioned the beds to a distance of 750 feet above the Herrin coal are chiefly shale, in which thin and probably local beds of coal and some black shale are interstratified. As shown in the log of the deep hole drilled at Henshaw, the shale becomes increasingly sandy up to 750 feet, and is there overlain by 65 feet of sandstone. Midway between Henshaw

and Grangertown is a range of hills capped by sandstone, which, however, seems to occur at a slightly lower horizon. This range of hills extends for some 7 miles to the southeast and dies out in a group of low hills outside the area under discussion. The length of the outcrop is no doubt a direct measure of the lateral extent of this sandstone bed, for the topography in this area is extremely responsive to the presence of hard beds interstratified with the softer shale.

Northwest of Grove Center a similar range of low hills extends for about 3 miles, curving from northwest to north, with indeterminate outcrops of sandy shale and thin sandstone which is believed to represent approximately the same horizon.

At a distance of 910 feet above the base of the formation, 5 feet of limestone is reported in the log at Henshaw. This limestone is rather impure, as indicated by bowlders near its outcrop, on the road 1 mile west of Henshaw. At what is believed to be the same horizon in the eastern part of Union County, about 10 feet of fossiliferous limestone outcrops in the bed of a small drain. Where this limestone has been weathered, however, it is composed of highly micaceous sandy shale, but in the fresh rock this character is not apparent. It seems likely, therefore, that some of the limestones reported in drill logs do not appear to outcrop for the reason that being impure the leached and weathered outcrop does not suggest its calcareous nature. In the log at Henshaw this limestone is overlain by 22 inches of coal. The greater part of the interval from this coal to the top of the formation, 80 feet, is neither exposed at the surface nor revealed by the logs, but it probably consists chiefly of shale. The Geiger Lake coal which has been mined locally at a number of points near Henshaw occurs 5 to 8 feet below the top of the formation. This coal was reported by Glenn to be 4 feet thick at the Runyon opening, near the south end of Geiger Lake, but the opening is now caved. The coal contained several partings of clay and bone.

The interval of 5 to 8 feet usually observed between the top of this coal and the sandstone at the base of the succeeding formations is occupied by thin beds of sand and micaceous and sandy shale beds.

The upper part of the following section is taken from the log of the well drilled near Henshaw by Mr. I. V. Runyon, to which has been added at the top 33 feet measured from outcrops in the vicinity, and at the base 485 feet from a well drilled north of Sturgis.

Section of the McLeansboro Formation.

	Feet	Inches
Shale, micaceous, sandy	6	
Coal, Geiger Lake	3	
Not exposed, probably sandy shale	60	
Black shale	4	6
Fire clay and shale	12	2
Coal	1	10
Bastard lime	4	7
Fire clay and soapstone	10	2
Sandy shale and soapstone	44	
Sand rock and shale	12	
Light shale	15	6
Sand rock	67	
Dark sandy shale	80	
Light slate	13	
Black slate	5	5
Coal		4
Fire clay	9	8
Light shale	8	
Light sandy shale	14	
Dark sandy shale	13	
Sandy shale	34	
Slate and shale	4	
Fossiliferous slate		2
Black slate		2
Coal		6
Fire clay	7	2
Fire clay and shale	11	
Black slate	12	
Coal		9
Fire clay	1	3
Light shale	16	6
Coal		2
Fire clay	4	4
Fire clay and slate	6	
Dark shale	1	
Sandy shale	12	
Dark sandy shale	13	
Dark shale	11	6
Shale and slate	6	6

	Feet	Inches
Limestone, exposed at Grundy Knob	7	6
Black slate	1	6
Coal		5
Fire clay	5	7
Sandy shale	22	
Dark shale	6	
Slate and shale	4	
Slate with coal streaks		6
Fire clay		2
Sandy shale	28	4
Sandy shale (dark)	4	
Dark shale	8	
Shale	25	
Black shale	5	
Blue shale	15	
Conglomerate	2	
Sandy shale	78	
Blue shale with hard bands	30	3
Coal		7
Fire clay	2	
Sandstone	1	2
Shaly sandstone	19	
Shale with limestone partings	20	
Shale	10	
Limestone	5	
Shale	7	6
Coal		4
Sandy shale	32	2
Blue shale	11	
Dark shale	4	
Coal		9
Fire clay	13	9
Dark shale	15	
Shale with hard bands	28	
Tough blue shale with hard bands	23	5
Coal	1	8
Dark shale	2	11
Gray shale	2	
Hard limestone	7	
Limestone with shale partings	9	
Limestone	2	
Blue shale with hard bands	8	
Coal (doubtful)		3
Limestone	1	6
Top of Herrin or No. 11 coal of Carbondale formation		
Total	996	5

HENSHAW FORMATION

The Henshaw formation includes all the beds of Pennsylvanian age in this area above the McLeansboro formation. Only its basal member is exposed. This is a thick massive sandstone of medium to coarse grain, often clean and locally of saccharoidal texture in the upper part. Its thickness varies from 15 to 35 feet, and in the area here under consideration its average thickness is about 25 feet. It is probably the most extensively outcropping bed in the area. It caps the group of hills northwest of Henshaw and is extensively exposed throughout the synclinal basin to the southwest. At the Wheeler water well what is probably the Geiger Lake coal occurs 60 feet below the surface, and there is therefore beneath the loess covering the ridge, which is here 25 feet thick, about 30 feet of beds above the top of the basal sandstone member. Farther north, in the vicinity of Shiloh school, as much as 150 feet of the beds of this formation may be present. They consist of sandy shales and sandstones in which is included a thin bed of coal believed to lie approximately 100 feet above the base of the formation. Owing to the inadequate exposures and gentle warped structure no section of any value could be measured.

TERTIARY SYSTEM

The only post-Pennsyvanian deposits in the area of pre-Pleistocene age are represented by remnants of a once extensive gravel deposit which now caps the highest hills in the area. One-half mile north of the Mt. Olive church, northwest of Henshaw, the following section was measured in the road cut at the crest of the ridge:

	Feet	Inches
Loess	16	
Red clay, somewhat sandy	1	6
Gravel, chiefly yellow, rounded cherts with some quartz pebbles locally cemented with limonite		4
Tough red clay becoming yellowish toward base with fragments of underlying Pennsylvanian rock material, grading into white clay shale and yellowish clay shale	2	
Pennsylvanian shale.		

The base of the section is 545 feet above sea level.

On the high point west of the Shiloh school the cemented conglomerate is a conspicuous constituent of the talus and pebbles derived from it are found to a height of 565 feet. No exposures occur but it is probable that the base of the deposit is somewhat lower.

This early river gravel was deposited during the Tertiary period and is found in scattered remnants throughout the Mississippi basin. The gravel was deposited before the cutting of the present valley of the Ohio, but it is probable that the forerunner of this stream was the agent of transportation.

QUATERNARY SYSTEM.

LOESS.—The ice which covered so much of the area of North America north of the Ohio River during Pleistocene times did not extend so far south as the area under consideration, and there is therefore no glacial till mantling the surface here as there is farther north. At the end of the glacial epoch, or perhaps while it was still going on, fine clay was transported to the area by the streams flowing from the end of the melting ice. This was deposited on the alluvial flats and whirled up in dust clouds which settled in the territory adjacent to the main drainage lines and to some extent far back into the interior. This is the loess deposit which, except in places where the original surface was too steep to retain it, completely covers the area to a depth of over 40 feet in the north and from 15 to 25 feet deep in the southern part.

TERRACES.—The Ohio River valley and that of the tributaries was formerly much deeper than it is at present. Drill holes in the flats near Sturgis, Ky., and elsewhere show that Cypress Creek, now a small stream, flowed at one time in a valley over 100 feet deeper than it is at present. Subsequently, probably during a period of subsidence of the continent, the valley was filled to the level of the upper flat so conspicuous a mile or so back from the present flood plain. The present elevation of this plain is 370 feet above sea level, and it is so nearly flat

that over a wide expanse in Gallatin County, Ill., and Union County, Kentucky, it may be used as a datum plane for setting an aneroid barometer without fear of an error greater than 5 feet. Since the formation of this plain the river has again begun to cut downward and the level of the present flood plain is approximately 350 feet. The relation of these movements to the time of the ice is somewhat uncertain. No glacial bowlders have been found lying on either of the flood plains, which suggests that the 370 flat as well as the 350 flat is of post-glacial age. Glacial bowlders have, however, been found at the base of the bluffs at several points and on the slopes to an elevation of 400 feet. This indicates rather clearly that during the time when the ice covered the land to the north the Ohio valley was flooded at least to the position of the 400-foot contour. The only means of transportation of such bowlders as have been found is that of floating ice which dropped its load of bowlders and gravel along the shores of the basin as the ice melted. A bowlder was reported at a depth of 73 feet in a well drilled in the 370-foot flat near Henshaw, and this suggests that the filling of the valley took place to a considerable extent during the ice age, and that by the time the valley had become filled to this level the water had retreated, leaving a great alluvial flat from which the winds whipped the dust which has settled so thickly on the uplands. Along the bluffs at the western edge of Bald Knob, considerable fine dune sand is present which may represent a more recent aeolian deposit derived from the present flood plain.

It is possible that a still earlier epoch of valley filling is represented by a group of hills having an elevation of 410 to 420 feet, which interrupt the smooth surface of Cypress valley southwest of Henshaw. A group of hills of about the same elevation blocks the natural drainage outlet of the basin just south of Grove Center.

No evidence is available in regard to the depth to consolidated rock on any of these mounds. As the hills are, however, covered with 25 feet of loess the average elevation of the bare hills must be about 385 to 390 feet. The configuration of the hills suggests that the remnants of the older valley fill (if such they be) had suffered consid-

erable erosion before being covered with loess and the plain which they seem to represent may have been slightly higher.

On the whole, the evidence so far as it goes parallels the conditions described by E. W. Shaw* in the Big Muddy River of Illinois, where an earlier and later valley fill, at elevations of 410 feet and 385 feet, are suggested by the deposits filling that valley. The earlier fill there is covered by loess and the later is not, as is the case in Union County. The difference in elevation between the two plains is also about the same and making allowance for the loess cover the difference in level is 15 to 20 feet in Union County, Kentucky, while it is reported to be 15 feet at Murphysboro. The surfaces are somewhat higher in Illinois than in Kentucky, but slight Pleistocene warping for portions of the Mississippi valley has already been suggested and if later investigations demonstrate that the terraces here suggested are the same as those in Illinois another step will have been taken toward the proof of this theory.

A valley fill older than that of the 370-foot flat and reaching an elevation of 400 feet would acount for the presence of glacial bowlders at this elevation at various localities, the presence of which on isolated hills within the Cypress valley presents a problem which the theory of transportation by ice does not entirely satisfy.

*E. W. Shaw, T. E. Savage, Murphysboro-Herrin folio, U. S. G. S. No. 185, p. 8, 1912.

CHAPTER II.—TOPOGRAPHY.

The topography of the area is remarkably responsive to the outcrop of hard beds. The strata consist almost entirely of materials of such contrasting hardness as shale or sandy shale, and sandstone. The softer beds are much more easily eroded and consequently underlie the valleys. The sandstones, on the contrary, cap the hills and ridges and it is very clear that all the ridges in the southern half of the region under consideration owe their preservation to beds of sandstones. Where hard lenticular sandstone beds wedge out the hills disappear or become inconspicuous along the strike. It is therefore not illogical to conclude that well defined ridges and hills in most cases represent outcrops of sandstone even where the thick loess covers the outcrops and the sandstone can not be seen. This conclusion, though it has very little quantitative value, has been used to some extent in determining the direction of strike of the beds in areas in which no exposures occur.

One mile south of Spring Grove an elongated basin or shallow sink-like depression occurs, paralleling a series of low hills. No outcrops are visible, but it is believed that the depression is in reality a sink caused by the solution of an uptilted limestone bed, perhaps that horizon lying above the Herrin coal.

Bald Knob is due to the presence of upturned Caseyville sandstone. The bow-shaped flat on the north is no doubt due to the early meanderings of the Ohio.

The lower course of Cypress Creek, which now flows into Tradewater River a mile east of the area, originally flowed in the opposite direction in a much deeper channel, draining the region of the Pond Fork flats in the western part of the county and joining the Ohio through the gap in the bluffs north of Anvil Rock. The drainage from the part of the valley below Henshaw and the waters south of Grove Center flowed as now southwestward but emptied, like the lower part of the valley, into the Ohio River north of Anvil Rock. The waters of upper Cypress Creek valley east of Blue Ridge bridge turned northward west of this point and emptied into the Ohio through an

abandoned channel just west of Spring Grove. All of these streams, as has already been mentioned, flowed in valleys very much deeper than those of the present day and the drainage basins were separated from each other by low ridges. With the submergence and filling of the valleys the gaps in the hills were obliterated and the openings into the Ohio were probably silted up to a higher level than in the remoter parts of the valleys. When, therefore, erosion was renewed by the withdrawal of water from the valley, the drainage found easier exit in an indirect course across the old and buried gaps between the streams through the chain of old valleys to the Tradewater.

The Tradewater itself has probably suffered little change in its course. Before the valley filling, the stream flowed as now, at least in its lower course, in a narrow channel cut through the hard and resistant Caseyville sandstone. An old meander where the valley was widened in passing across softer beds is visible 2 miles above its mouth. The only effect, therefore, of valley filling was to raise the floor and to fill in with flats the broader parts of the valley.

CHAPTER III.—STRUCTURE.

The structure of the area is complicated and its study greatly hampered by the deep loess covering which conceals the rocks. It has been found possible, however, to show the deformation of the beds by 50-foot contours, though in certain areas where information is inadequate uncertainty is indicated by drawing the contours in broken lines. (See Plate I.)

In its simplest aspect the structure south of the Rough Creek fault, consists of an asymmetrical syncline extending from the southern margin of the area northeast to the Rough Creek fault and with its axis roughly parallel to the fault. The Rough Creek fault passes southeast along the north side of Bald Knob. The maximum deformation within the area is about 2200 feet, the axis of the syncline being about one-third of the distance from the north side of the trough. North of the zone of faulting the rocks in this area slope northwestward at the rate of about 125 feet to the mile. Both north and south of the fault the structure is complicated by warping and subsidiary faults and folds.

The impression prevails among many people in the coal mining area between Dekoven and Sturgis that the coal beds have a dip of 1 foot in 12. While this is locally true, there are wide variations in the dip in the same mine. The average dip in 2 mines north of Grangertown is 1 in 16, while the average dip north of Dekoven is about 1 in 13. In the Bell-Union mine the average dip is said to be 1 in 13. In some of the mines the dip decreases to such an extent as to give barely enough slope to carry the empty cars back into the lower levels, while steeper slopes occur above and below. At the Bell-Union mine the strike is said to be N. 73° W., near Dekoven it is approximately N. 70° W., north of Grangertown it is N. 65° W., and farther eastward the strike is more strongly toward the northwest. This change in the direction of the strike is probably the cause of the displacement of a wedge shaped block south of Tradewater River, to be described later.

From its outcrop between Dekoven and Sturgis the Springfield coal dips as described somewhat east of north

to a line drawn from a point 1 mile south of Henshaw to the vicinity of St. Ambrose church. Farther northward the dips flatten more gently and within a strip from 1½ to 2 miles wide the structure, as indicated by the Geiger Lake coal and the basal sandstone of the Henshaw formation, is irregularly warped and deformed, with, however, a general northward dip to the vicinity of Shiloh school, which lies at or near the deepest part of the structural basin. The synclinal trough extends roughly S. 60° E. from Shiloh school and is not so deep immediately east of Henshaw, though known to be deeper again in the eastern part of Union County. The axis of the syncline is believed to turn near this point and west of the school to have a nearly westward trend, as shown on the structure map.

From the axis of the syncline the beds rise more sharply to the north than to the south and on the north limb the structure is more complex.

One mile north of Shiloh school two wells drilled for water on the farms of William Vaughn and Frank Detraz are reported to penetrate 4 feet of coal at depths of 44 feet and 40 feet respectively. This coal is believed to be the Geiger Lake coal, chiefly because of its short distance from known outcrops of this coal and because there is no evidence to show either sharp dips or faulting in the intervening area.

On the low hill northwest of Grove Center there is abundant evidence of sharp deformation, dips of 10° and 16° having been observed in the outcrops. It is believed that this ridge, which is capped by sandstone, is continued in the northward swinging ridge on the northwest side of Cypress Creek at this point, and that the series of parallel hills is the topographic expression of a series of hard sandstone strata dipping toward the southwest. The structural half-dome, tentatively shown north of Grove Center, is postulated chiefly on topographic forms, a few observed dips and the perhaps somewhat questionable correlation of thin coals reported as occurring in water wells in the vicinity.

On the crest of Bald Knob two beds of conglomeratic sandstone outcrop, dipping 35°, S. 20° W., one on the north side and one on the south of the ridge. These beds

of sandstone are, so far as the exposures indicate, approximately the same thickness and the stratigraphic interval between them is the same as in the conglomeratic beds of the Caseyville sandstone along the Ohio River, and it is believed therefore that they are the same. These beds are the most resistant beds in the entire Pennsylvanian series and never fail to find expression in the topography. When, therefore, along the strike east of the exposures, the high hills are suddenly cut off and give place to a series of low hills running almost at right angles to the strike of the conglomeratic sandstone, the presence of a diagonal fault is strongly suggested and the fault shown here is based on this conclusion. West of the conglomeratic sandstone exposure there seems to be another diagonal fault, or perhaps a group of faults, for the conglomeratic beds give place along the strike to nonpebbly sandstones and thick coals, while the conglomerate is offset several hundred yards to the north. The position of this fault as shown, is located within certain definite limits by the outcrops of the offset conglomerate, but the position of neither of these diagonal faults could be determined with exactness and it is probable that there is really a series of similar subordinate faults, the ones plotted indicating the net result of a series of displacements of the strata.

The assumption of faulting of such remarkable character as indicated by the triangular shaped block included between these faults would require more justification if it were not a common type of displacement along the Rough Creek fault. It will be observed that the block in question has been thrust up from below much higher than the adjoining blocks on any side. What the character of strain may have been which produced this reverse block faulting is not known, but it is not an uncommon phenomenon in the eastern part of Union County, where similar isolated blocks have been thrust up, and along the continuation of the Rough Creek fault in Illinois where, in one case, a block has been thrust upward some 2000 feet higher than the once continuous surrounding beds.

Along the bluffs south from "The Rocks" a number of exposures of dipping sandstones occur, but none can be

identified though all are believed to occur above the Caseyville sandstone. Near the north end of Geiger Lake they have a southerly dip of 4° to 10°, but as "The Rocks" are approached dips of 26° and more are observable. The dips are so steep in the disturbed area about Bald Knob that it would be impracticable to show structure contours even were sufficiently accurate data available. An effort has been made, however, to show the approximate outcrop lines of the principal coal beds. These are based entirely on coals reported to have been found in drilled water wells. Estimates have been made so far as possible of the intervals between the beds, taking into account the dip and horizontal distance between wells as well as the offset along the strike and depth of coal below the surface and the exaggeration of the thickness of the coal due to the inclination of the strata. It is believed that the Davis and Springfield coals have been penetrated in wells near Bald Knob at the places indicated in the appended table. The outcrop lines as shown, have been drawn to conform as far as possible with the strike, the topography, and so as to avoid interference with negative or conflicting information, but since the slopes are deeply covered with loess and the presence of faulting is suspected, the outcrops as shown are admittedly largely speculative.

The Rough Creek fault has a downward displacement on the north side of Bald Knob of 1600 to 2200 feet, but the warping of the beds on both sides of the fault renders the stratigraphic displacement a variable quantity, and if the interpretation of the structure is correct, the displacement south of Spring Grove amounts locally to only a few hundred feet. This fluctuation in amount of throw is common in other parts of the Rough Creek fault, and if the trace of a single bed could be examined on the fault plane it would be found to follow a rudely undulating line, high at one point and low at another, transforming the edge of the synclinal block into a succession of tremendous scallops broken by faults of the nature already described, often of considerable magnitude.

The fault itself is probably not a clean break but a faulted zone. On the accompanying map, it is shown as a line combining the direction of faulting indicated in the

river front exposures at Shawneetown and that indicated in the Chalybeate Hills to the east, and excludes on the north areas known or believed to be outside the synclinal block.

North of the Rough Creek fault the structural deformations are much more gentle. From Spring Grove, where the Herrin coal outcrops, the beds dip west of north at the rate of about 125 feet to the mile. Toward the east, outside the area, the dip of the beds seems to be east or northeasterly. The coals at Morganfield, 5 miles distant, are 225 feet lower than those near Spring Grove, and at Uniontown, 3½ miles northeast of the quadrangle, the coals are 100 feet lower than at Spring Grove but nearly 300 feet higher than at Grundy Knob. These facts suggest that a pitching anticline extends northeastward from the vicinity of Spring Grove towards Uniontown.

The structure shown beneath the flood plain of the Ohio north of Bald Knob is largely speculative, as there are neither outcrops nor borings of any kind. At the edge of the flood plain north of Bald Knob, however, several small bowlders of Pennsylvanian limestone were noted in a small drain, and as well borings in the vicinity demonstrate that there is no coal for a depth of over 250 feet below the surface, it is believed that these may represent a concealed outcrop of the limestone exposed on Grundy Knob. Except for this there is no clue to the structure on the Kentucky shore, but on the Illinois shore exposures and drill holes north and west of Shawneetown suggest that the valley of the Ohio occupies a synclinal area, which is consistent with the supposed outcrop of the limestone in Kentucky. This synclinal structure is shown on the map by dotted lines, but no details of the warped surface are known.

South of Tradewater River two faults drop a block of Tradewater beds 200 feet. This block is probably wedge-shaped, and lies in the angle made by the change in strike observed in the Springfield coal. The displacement throws the outcrop of the Bell coal 1½ miles to the west. The faults can be clearly seen in the river bluffs from a boat, and the southern of the two faults is clearly exposed near the head of a heavily wooded ravine a little

less than a mile south of east of the mouth of the Tradewater. No other exposures of these faults are known, but the displacement of the beds recognized in the borings at the Rutherford school and near the Hazel Branch ferry and at the old Smith mine give some idea of the shape of the faulted block. No displacement of the Springfield coal, however, appears to have occurred and it seems necessary to conclude that the wedge-shaped end of the block lies to the west of the outcrop of this coal. The section on the river bluff shows that the block has been under compression and that like the block faults in Hardin County, it has been flexed into a syncline.

A few subsidiary faults are known. One occurs east of Caseyville, having a strike of N. 60° W., with a downward displacement of 30 feet on the northeast side. The fault is indicated by edgewise sandstone in the road and distorted shales near the first bridge on the road entering the town from the east. The coal on the north side outcrops in the bed of the creek, while on the other side it outcrops at the Old Murphy or Bohannon mine near by. A small fault occurs near the entry to Barnaby's mine on the southern margin of the area. This fault strikes N. 15° E. and has a displacement of 15 feet downward on the east side.

Similar small faults occur in several of the coal mines operating north of the Tradewater between Sturgis and Dekoven. In the Ohio valley mine a small block about 100 feet in diameter has been dropped 5 to 20 feet between two slightly diverging faults having an average strike of N. 60° W.

In the No. 8 mine of the Western Kentucky Coal Company two small faults, nowhere in excess of 10 feet, strike N. 45° E. and N. 55° E. respectively, approximately paralleling a synclinal warping which interrupts the smooth northeastward dip of the coal bed.

CHAPTER IV.—ECONOMIC DEPOSITS

The only economic deposit of any value in the area is coal. Interest in oil has been manifested from time to time but the indications are not very promising.

OIL

When the oil-bearing rocks are saturated with water, oil is found in porous strata underlying impervious beds in anticlinal areas or in analogous positions in other rock structures. The area of this report does not contain any area known to fulfill these favorable conditions with the possible exception of the faulted dome just east of Spring Grove. This dome, as shown on the structure map, is to a certain extent of a hypothetical character, too little data being available for the exact delineation of the structure at this point. The possibility of dome structure at this point should not be overlooked, however, and even though the Rough Creek fault zone passes directly across the arch, the possibility of retention of oil is not entirely eliminated, since the argillaceous character of the beds at the surface might be effective in closing the zone of faulting to the circulation and escape of oil.

In a water well drilled on the farm of Sol Blue, 1 mile east of Spring Grove, a strong odor of kerosene was reported at a depth of 115 feet, just below the horizon of the Herrin coal. While this in itself is not particularly significant, the fact that it occurs near the crest of a probable dome is worthy of some consideration in spite of the unfavorable proximity of so prominent a zone of faulting as that mentioned.

The water from a comparatively shallow well recently drilled a mile south of Sturgis, shows a faint film of oil on the surface and a faint odor of kerosene, but the conditions do not appear to exclude entirely the possibility of accidental contamination, and there is nothing in the structure of the immediate area to warrant any excitement.

Salt water and gas are reported to have been found in a water well drilled many years ago, of unknown but probably not great depth, in the flood plain of the Ohio

1½ miles northeast of Grundy Knob. The structure in a northeast-southwest direction is clearly shown for several miles in exposures along the bluff and in this direction the beds lie almost flat. Whether there is any deformation at right angles to the exposures is not known, but it is questionable if a reversal of the dip sufficient to provide a suitable reservoir occurs.

The area south of the Rough Creek fault is a very distinct syncline; there does not appear to be any part of the basin structurally competent to provide a reservoir. It is possible that certain tilted lenticular sandstone beds inclosed in shale may provide conditions theoretically favorable to the retention of oil, but the inclosing shales are usually so sandy and so pervious that such conditions do not offer much encouragement.

North of the Rough Creek fault the beds rise toward the south, i. e., toward the fault zone, so that the possibility of the retention of oil seems to be precluded by the natural tendency of any oil which may have been present to rise and escape first along the bedding planes and then through openings in the faulted zone. If it be assumed that the argillaceous elements of the coal measures have been dragged into the fault planes in such a way as to close the faults to the circulation and escape of the petroleum, as sometimes occurs, the conditions just south of the fault may prove to be favorable in some places betwen the sealed off fault plane and the beds which dip steeply to the southwest. While nothing is positively known to the contrary concerning the Rough Creek fault, the width of the zone of faulting, the ragged fault line, and the changing direction of the fault do not suggest very strongly that the breaks have been very effectively sealed against circulation.

COAL

THE USE OF NUMERICAL DESIGNATIONS FOR COAL BEDS

The use of numerals to designate the coal beds, introduced by the early geologists, has been the cause of great confusion in the discussion and comparison of coals of different localities. The No. 11 coal bed of Kentucky, for example, was designated as No. 7 in Gallatin County,

Illinois, and through mistaken correlation was called No. 6 in central Illinois. In Indiana it was given still another numerical name. The system was based on the erroneous idea that the coal beds were continuous over large areas and it was even presumed that the principal coal beds had once been continuous from the Appalachian Mountains to Arkansas. The fallacy of this early conception has long since been recognized, but the determination of each of the early State geologists to trace each coal throughout his respective state led to the numbering of the workable coals in regular order from the base of the section upward. Such a system failed to take into consideration the fact that some of the beds were of local development only, while in other localities coals were later found to lie between those originally numbered. The Briar Hill coal, for example, is not known in central Illinois, and the Curlew, Ice House and No. 2 coals observed by Owen on the Ohio River bluffs, have been demonstrated to be entirely absent at many localities not far distant, while other coal beds not recognized by Owen have been found to lie between the carefully numbered beds observed in the outcrops.

The complete failure of such an inflexible system was recognized too late to avoid the difficulties involved, but it is now the effort to substitute geographic names for the numerals so far as is possible without creating additional confusion. Table No. 2 indicates the correlation of the variously named coals and shows the usage adopted by the U. S. Geological Survey which is incorporated in this report.

TABLE NO. 2.

Table Showing Nam es Applied to Coals of Illinois and Union County, Kentucky.

Owen	Worthen	Present Usage.			
Kentucky, 1858	Gallatin County, Illinois, 1875	Gallatin County, Illinois	Illinois	Union County	This Report
11	6	7	Herrin	11	Herrin.
10	5½	6		10	Briar Hill.
9...Mulford	5	5	Springfield / Harrisburg	9	Springfield
8...Well		4		8	Well.
7					
6 ... Little coal / 3-foot coal		3		7	DeKoven.
5...Four-foot coal		2	Murphysboro	6	Davis.
4...Curlew					Curlew.
3...Ice House					Smith.
2					Ice House.
1-B...Bell					Bell.
1-A					
Battery Rock					Battery Rock.

General Character of Coals

The coal of the area is of high quality and ranks with the best coals of the Eastern Interior coal basin. The fixed carbon ranges from 55.14 per cent. to 58.7 per cent. in the pure coal and the fuel ratio south of the Rough Creek fault from 1.25 to 1.86. The calorific value of the coal as received, measured in British thermal units, ranges from 12,000 to 13,490, averaging over 12,500 for the Springfield coal and over 13,000 for the Davis coal.

Table No. 4 shows all the analyses by the Bureau of Mines of samples taken from mines in the area. Most of the samples were taken prior to the season of 1915 under a co-operative agreement between the Bureau of Mines and the Kentucky Geological Survey, but six new samples taken by the writer from country banks working on beds not previously sampled are added. Two of the analyses, those of the Smith coal, were made by the Bureau of Mines in 1906. To this have been added several average analyses of the best coals for purposes of comparison.

The percentage of ash ranges from 11 per cent. in the Springfield or No. 9 coal, to 5 per cent. in the coal at the abandoned Smith mine. With the exception of the Smith and Bell coals, the ash is in general too high to make a good coke though it was at one time manufactured at the Ohio Valley Coal and Mining Company, at Dekoven, from the Springfield coal.

The sulphur in most of the coal beds averages from 3.5 per cent. to 4 per cent., but two Bureau of Mines analyses and numerous private assays of the Smith coal show that it rarely carries more than 1 per cent. of sulphur.

The amount of moisture in the Tradewater coals south of the Rough Creek fault is notably less than that in the same beds north of this structural break. The percentage of fixed carbon present in the coals, the fuel ratio (the percentage of fixed carbon divided by the percentage of volatile matter) and the fuel value are all notably higher south of the fault than north of it in the coals for which comparative analyses are available. The aver-

age analyses arranged according to localities are shown in Table No. 3.

A glance at the structural map shows that the area south of the Rough Creek fault has suffered much greater deformation than the area on the north. The changes in the coal therefore seem to be distinctly attributable to increased stress and readjustment due to the folding in the area south of the fault. It also supports the conclusion (arrived at by other lines of reasoning) that the thrust which caused the deformation came from the south, the undeformed area north of the fault acting as an unyielding buttress, so that the transmitted force expended itself in lifting and deforming the area on the south and in friction in the fault zone.

Unfortunately only two analyses of the Springfield coal are available in Kentucky north of the fault, both of these near Sebree, but average analyses of the same coal from central and southern Indiana have been introduced in Table No. 3 to demonstrate the character of this coal north of the zone of faulting. All of the analyses used have been made by the Bureau of Mines, from mine samples collected and analyzed under the uniform methods adopted, so that the results are strictly comparable. The averages given for this area were made from analyses of samples taken at localities north and south of the fault only 10 or 12 miles apart. Similar changes in the character of coal are known in all folded areas, the transition being a gradual one as a usual thing from undeformed beds in one area to more or less closely folded areas some distance away as in Montana and Pennsylvania where the value of the coal is greatly increased by the deformation.

The abruptness in the change in the coal which appears to take place at the fault indicates rather strongly that the coal in unprospected areas in Union County, north of the fault, will be of a somewhat lower grade than that in the folded area on the south represented by the coal mined along Tradewater River.

GEIGER LAKE COAL

The Geiger Lake coal is irregular in thickness and is damaged by the presence of clay and bone partings. On the river bluffs west of Henshaw two openings have been made, but both are abandoned. One of these was reported by Glenn to be 4 feet 1 inch thick, including 10 inches of clay and bone in three partings. On the Henshaw farm, 1 mile north of Henshaw, another opening has been made. The coal is said to be 33 inches thick. Only the upper 20 inches could be examined, but this included a parting of 10 inches of gray clay which was said to decrease to one-half inch, 30 feet from the mouth of the drift. The lower part is reported to be comparatively free of ash. Another opening of this coal was examined on the Lloyd Brown farm 1¼ miles south of Grove Center. Here the coal is only 2 feet thick, the upper part being somewhat flaky, due perhaps to weathering. The lower part is clean and blocky. The coal does not offer much inducement to further prospecting.

THE HERRIN COAL OR NO. 11 COAL

The coal designated No. 11 by D. D. Owen has been found by stratigraphic studies to be the equivalent of the Herrin or No. 6 coal of central Illinois, which was at one time referred to as No. 7 in Gallatin and Saline counties in the same state. Its persistent and uniform character throughout central and southern Illinois is locally interrupted in Union County, Kentucky. The bed is thin and irregular in thickness in some places and near Dekoven lenticular bodies of cannel coal are said to have been mined from it for the use of signal fires during the Civil War. No workings in the coal near Dekoven are now open, but at the head of a hollow east of the Bell-Union mine the following section was reported at a prospect slope:

	Feet	Inches
Slate.		
Cannel coal	2	0
"Blue band" fire clay		4
Bituminous coal		4
Fire clay.		
Total	2	8

In the slope 100 feet from the mouth of the prospect, the upper bench had decreased in thickness to 14 inches and was said to contain streaks of bituminous coal.

At the Buchanan mine, three-fourths mile northeast of Grove Center, the following section was measured:

	Feet	Inches
Black slate.		
Coal		8
Marcasite		½
Coal		9
Marcasite		⅛
Coal		5
Mother coal		⅜
Coal		9
Coal with streaks of marcasite		1½
Coal		3
"Blue band" fire clay		2¼
Coal		7
Hard fire clay.		
Total	3	9¾

The Herrin coal is characterized by a band of bluish fire-clay a short distance above the base and by the tendency of the coal to separate in mining into three benches. On account of these characteristics it is often referred to as the "Blue band" coal or the "Bench" coal. The coal is bright and clean and is streaked with bands of contrasting luster. Slivers of it are easily ignited and while the coal is bituminous it probably contains to a minor degree some of the constituents of cannel coal.

The bed at the Buchanan mine contains a good deal of marcasite, but this occurs chiefly in sheets and lenses which can be thrown out in mining. The proximate analysis at this mine approaches closely the average of the Herrin coal north of the fault, though it is slightly higher in the proportion of fixed carbon.

North of the fault the coal compares favorably with the coals of Indiana and central and northern Illinois. South of the fault, as shown by analyses in Webster County, the heat value is considerably increased by loss of moisture and increase in the fuel ratio, and it has, as

may be noted in Table No. 3, a calorific value as mined of 12,400 British thermal units. The sulphur and ash are both a little above the average of Illinois and Indiana coals, but the fuel value as already mentioned is higher.

THE BRIAR HILL COAL OR NO. 10 COAL

The Briar Hill coal, called No. 10 by Owen, is mined at present in two small mines serving the country trade at Dekoven. In quality it compares very favorably with the Springfield or No. 9 coal. It has about the same ash and sulphur content but the percentage of fixed carbon in the pure coal is slightly higher than the Springfield coal, though this does not affect the calorific value. The similarity of the analyses of the samples taken from the two mines, which are over a mile apart, is remarkable. Physically it is black, lustrous, and rather brittle, and it is said to ignite easily, making a quick fire. The bed is less than 3 feet thick at Dekoven and this serves at present to prevent its commercial exploitation. The following sections were measured at the Banks and Syres mines at the points sampled:

Section of Briar Hill Coal at Banks Mine, Dekoven, Ky.

	Feet	Inches
Gray "slate."		
Bone coal adhering to roof		½
Coal	1	10
Marcasite		⅛
Coal		10
Hard fire clay.		
Total	2	8⅝

Section of Briar Hill Coal at Syres Mine, Dekoven, Ky.

	Feet	Inches
Gray slate.		
Coal	2	10
Hard fire clay.		
Total	2	10

THE SPRINGFIELD COAL OR NO. 9 COAL

The coal called No. 9 by Owen is the same coal mined extensively at Springfield, Harrisburg and elsewhere in Illinois, where it was originally known as No. 5 but where it is now known as the Springfield coal.

It is the chief coal mined in Union County. Its high calorific value makes it a desirable coal for the consumer and its even thickness and character, its good roof and other favorable mining conditions make it a profitable coal for the producer. Although it slightly exceeds the coal from the same bed in Saline County, Illinois, in ash and sulphur content, it has a slightly higher calorific value than that coal and is much superior to the coal mined from the same bed in Indiana and central Illinois. Compared with coals in other parts of the basin it is exceeded in calorific value only by the Murphysboro coal of Illinois, which is also lower in both ash and sulphur. The calorific value of the two coals in the moisture and ash free state is nearly equal, the discrepancy in calorific value in favor of the Murphysboro coal being due to its low ash and sulphur content.

The bed over the coal is a tough black slate from 4 to 10 feet thick, which stands without timbering. Some of the openings in which the roof is still firm are said to have been open for fifteen or twenty years. Large black calcareous concretions from a few inches to 4 feet in longest diameter, occur in the lower part of the black slate. The laminae of the slate bend around these concretions and this, together with the fact that the concretions sometimes project into the coal, seems to indicate that their formation took place prior to the consolidation of the beds, at least prior to the consolidation of the coal. The black slate contains fossils in the lower part beautifully preserved in the pyrite, which when fresh looks almost like Japanese lacquer.

Between the black slate and the coal there is usually from 2 to 12 inches of hard, gray-black fire-clay which is taken down in mining as it makes an insecure roof.

The coal is of uniform character and appearance. The thickness of the bed is quite regular and varies only 3 or 4 inches more or less from 4 feet 10 inches. It is

black, with a slightly brownish streak, lustrous, rather brittle, and shows fine banding of coaly material of slightly contrasting luster. The fracture is rather uneven and the coal breaks in ragged squarish blocks. The cleat is indefinite and varies from place to place in the same mine. The bed contains usually a few thin partings of mother of coal or natural charcoal at irregular intervals and there are no clay partings. The bed, however, usually contains more or less marcasite in the lower part in sheets, lenses, or concretions, in such shape however that it can be thrown out in loading the cars. The coal is often closely and finely jointed and the cracks are cemented with films of gypsum or marcasite which no doubt contribute largely to the ash. The floor is fire-clay with stigmaria, and is quite hard, but when exposed to the air is likely to swell. The mines are not affected by rolls or horsebacks, but in the area between Sturgis and the Ohio River a few faults of small throw, 5 to 20 feet, are found which introduce some difficulties into mining operations. The local folds superimposed on the northeasterly dip parallel to these local faults have already been mentioned.

The following section was measured:

Section of Springfield Coal in Mine No. 8, West Kentucky Coal Co., Sturgis, Ky.

	Feet	Inches
Black slate	8	
Gray-black fire clay		8
Bony coal, adheres to roof		½
Coal, black, brittle, with thin streaks and concretions of muscovite in lower third	4	9
Coal rash		2
Hard fire clay.		
Total	4	11½

THE DEKOVEN OR NO. 7 COAL.

The Dekoven coal was called No. 6 by Owen, but modern usage of the numerals in Kentucky makes this the No. 7 coal. It has also been widely known as the 3-foot vein, and it is said to have been used formerly as a gas-

producing coal and for this reason has also been called the "Gas" coal. It is called the Dekoven coal because of the opening at Dekoven, the only place in the district where the coal is exposed for examination.

Unfortunately no modern analyses of the coal are available as no fresh exposures of the coal for sampling are now accessible. At Dekoven, where the coal was extensively mined, the coal has a thickness of 44 inches, though as a usual thing it is not more than 3 feet thick. Judging by the somewhat weathered face just inside the old entry near Dekoven station, the coal is apparently quite clean, with comparatively little marcasite in bands or streaks and without injurious partings. The coal is reported to be of excellent quality, and, as previously stated, is said to yield considerable gas and was once used for the production of gas for lighting purposes as well as for fuel.

The roof is a soft, micaceous, sandy shale, with fragments of macerated leaves. An irregularity in deposition at the top of the coal at the old Dekoven slope suggests a slight erosion interval prior to the deposition of the overlying shales.

THE DAVIS COAL OR NO. 6 COAL

The Davis coal was originally called No. 5 by Owen, but the present usage in the area is to refer to it as No. 6. It is also known as the 4-foot coal, on account of its assumed persistence at this thickness in contrast to the thinner overlying bed. It occupies nearly if not quite the same stratigraphic position as the Murphysboro coal of Illinois, with which it is provisionally correlated, though the exact stratigraphic equivalency is not positively determined. It is called the Davis coal from the Davis mine of the Crittenden Coal and Coke Company, where it is now mined in a small way.

The Davis coal is in some respects the most valuable coal in the eastern interior coal field. The three samples taken and analyzed under the uniform methods adopted by the Bureau of Mines, seem to demonstrate that this coal has a higher average heat value by 500 B. t. u. as

mined and by 300 B. t. u. in the moisture and ash free state than the Murphysboro coal of Illinois,* but it is exceeded in calorific value by two other coals in the Union County area, the Smith and Bell coals. Although the ash and sulphur of the Murphysboro coal in Illinois is lower than that of the Davis coal, the latter is yet well below the average of the coals of the Eastern Interior basin in both these constituents and is, on account of the deformation of the strata in the Union County area, much lower in moisture than any of the coals likely to be its competitors.

As compared with the Springfield coal of the same area, the Davis coal is slightly higher in the ratio of fixed carbon to volatile matter and distinctly lower in both ash and sulphur, while the heat value is considerably higher both in the fresh coal and in the moisture and ash free state. The superior quality of the coal, however, is to some extent offset by the roof, which consists of slaty shale and does not stand so well as that of the Springfield. The bed contains considerable marcasite, which must be separated and thrown out in loading, and while the bed is of regular and even thickness it averages only 3 feet 10 inches thick and is consequently for these reasons, less attractive at present for mining operations than the thicker Springfield coal with its firm roof.

The coal is bright and lustrous and slightly brittle, and is made up of thin coal sheets of contrasting luster. There are usually two or three discontinuous bands of marcasite, often over one-half inch thick, and marcasite also occurs as thin films on the closely spaced faces of joint cracks. Mother of coal streaks rarely more than one-eighth of an inch thick, are fairly common. There is locally one or two thin clay or bony partings less than one-eighth inch, though at one point a black bony streak one-half inch thick was noted near the top of the formation. That these impurities are of a subordinate nature, however, is shown by the low ash content of the analyses. The coal is reported to kindle easily and to make a quick hot fire. The following sections were measured:

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*Ill. Coal Mining Investigations, Ill. Geol. Surv. Bulletin No. 11, Coal Resources of District No. 7, by F. H. Kay, p. 41, 1915.

Sections of the Davis Coal in the Davis Mine, 3 Miles West of Sturgis, Ky.

	Feet	Inches
Slaty shale.		
Coal		1
Marcasite		½
Coal		3½
Bony clay		½
Coal with another coal parting and thin marcasite bands in upper part	2	
Mother coal		¼
Coal	1	4
Fire clay.		
Total	3	9¾

	Feet	Inches
Gray shale.		
Coal streaked with marcasite	1	11½
Marcasite		½
Coal		3
Marcasite		½
Hard coal		7
Marcasite		½
Hard coal		11
Fire clay.		
Total	3	10

THE SMITH COAL

The Smith coal is probably the equivalent of the coal noted above the Ice House coal in the ravine near Mulfordtown. Until recently this coal was believed to be the same as the Bell coal which outcrops and was extensively worked a short distance to the north. A drill hole, however, put down near the Rutherford school one-half mile west of the Smith mine demonstrates the fact that the Bell coal is really about 275 feet deeper and that the Smith opening is in the faulted block determined from outcrops farther west.

Analyses made by the Bureau of Mines from samples collected in 1906 were, because of this confusion, reported as the Bell coal, but it seems likely from the description of the localities in the mine and from the exceptionally low sulphur and ash content as well as the high fuel

ratio, that the samples were taken at the Smith slope of the Bell Coal and Mining Company, and not at the nearby abandoned Bell mines which had been reopened about the same time by this company. In support of this conclusion twenty analyses of samples taken from the Bell and Smith coals and analyzed under various private auspices show that the samples from the Smith mine approach closely in sulphur and ash content and in fuel ratio the results given in the early Bureau of Mines samples, while those from the Bell mine correspond to the results secured from the samples taken during the past season at the Barnaby and Newcome openings, where the Bell coal is now being mined.

The coal taken from the Smith mine has a higher fuel value than any known coal in the Eastern Interior coal field and combined with the high fuel ratio has also a remarkably low ash and sulphur content. While only two standard analyses of the coal are available, the general conclusions are substantiated by ten privately made analyses in all of which the above advantages are strongly accentuated. To what extent the high fuel ratio and calorific value may be due to the position of the opening in the compressed fault block is problematical, as no analyses of the coal at any other point are available for comparison. It is probable that its superior qualities may be due in part to its structural position, but its low ash and sulphur would be sufficient to make it an extremely desirable coal, especially for coking, even though the fuel ratio were not any higher than the other coals of the district. The higher moisture of this coal compared with other coals in the district, indicates that there has been little change in the coal due to its structural position in the compressed fault block or that the coal originally had an unusually high moisture content.

The very exceptional quality of this coal is offset by the comparative thinness of the bed and the comparatively limited amount of the coal available. The thickness of the coal at the Smith mine is said to be 3 feet 6 inches to 3 feet 4 inches, but the reports accompanying the analyses made by the Bureau of Mines give it a thickness of only 2 feet 7¼ and 2 feet 9¾ inches respectively.

The following section was reported at the point at which the sample for analysis No. 3679 was taken:

Section of Smith Coal at the Smith Mine, Crittenden County, 2½ Miles Southwest of Sturgis, Kentucky.

	Feet	Inches
Shale.		
Coal		10½
Mother coal		½
Coal		10
Mother coal		¼
Coal		5
Mother coal		⅛
Coal		7
Fire clay.		
	2	9⅜

THE BELL COAL

The Bell coal was named from the mines operated on Caney Creek south of the Tradewater, by John Bell, defeated Union candidate for President of the United States in 1860. It is No. 1 B in Owen's classification and is almost the only commercial bed in the district whose name and numerical designation have been used consistently. Its calorific value and fuel ratio are second only to those of the Smith coal, and exceed even the values of the Davis coal in both respects. In fact no known coal in the Eastern Interior coal basin, except the purely local Smith coal, approaches it in heat value. It is low in ash (4.4 per cent.) and at the places sampled is lower than the Murphysboro coal of Illinois. It contains, however, 3.43 per cent. sulphur at the places sampled though it is said to be lower in sulphur in the neighboring abandoned mines. This contention is supported by private analyses, more than half of which report sulphur below 2.5 per cent.

As in the case of the Davis coal, the exceptional value of the coal as fuel is offset to some extent by the conditions of its occurrence. The roof is a sandy micaceous shale which stands well for a time but is not so good as the roof of the Springfield coal. While the bed is said

not to be subject to rolls or horsebacks, the thickness of the bed varies somewhat from place to place. It is rarely more than 4 feet thick and locally in the mines is reported to become as thin as 2 feet, though only one of the eight drilled holes which have penetrated the coal indicates that it is less than 3 feet. From this thickness, however, must be deducted several inches for the rash which persistently underlies the coal.

The Bell coal, like most of the coal of the area, shows the fine pseudo-lamination produced by bands of varying degrees of luster. It has no cleat but has a conchoidal more or less smooth fracture. The bedding faces are lustrous and show a fine network of cracks filled with films of marcasite. Marcasite is present in lenses also but these do not form a common impurity. A little cannel coal never more than a few inches, is said to appear locally at the top of the bed. The rash which lies at the base of the bed is from a few inches to over ten inches thick. It is a soft, flaky, friable material of dull luster containing a considerable proportion of clay.

A sample collected from the rash at the Barnaby mine was found on destructive distillation to yield 14 gallons of coal tar and 12 gallons of water to the ton, the coal itself yielding 15 gallons of coal tar and 6 gallons of water, with an undetermined quantity of ammonium sulphate.

The following sections of the Bell coal were measured at the places sampled:

Section of Bell Coal at the C. T. Newcome Mine, in Crittenden County, 4 Miles South of Sturgis, Kentucky.

	Feet	Inches
Micaceous sandy shale.		
Coal		5
Mother coal		⅛
Coal		10
Mother coal		½
Coal, hard and lustrous	2	2½
Rash		10
Fire clay.		
	4	4⅛

Section of Bell Coal at the F. M. Barnaby Mine, in Crittenden County, 4 Miles South of Sturgis, Kentucky.

	Feet	Inches
Sandy micaceous shale.		
Coal		4
Mother coal		⅛
Coal		10
Mother coal		⅛
Coal		4
Coal, hard and lustrous	1	11
Rash		8
Fire clay.		
	4	4¼

The coal does not deteriorate very rapidly. The old stock piles at the Bell mine, said to have been exposed to the air for thirty years or more, are still fresh looking. A grab sample taken from one of these stock piles was analyzed under private auspices, together with a mine sample and was found to be only 5 per cent. inferior in calorific value to the fresh coal.

DEPTH OF COAL

The depth to the Springfield or No. 9 coal at the localities mentioned is given below. As the beds in most cases are dipping rather strongly and as the surface of the No. 9 coal is considerably warped by secondary structure, some latitude must be allowed.

	Feet
Shiloh school	1260
Henshaw	1080
Grove Center	650 to 750 (?)
Flood plain at Grundy Knob	500
Spring Grove	150
Geiger Lake	1100
St. Ambrose church	950

It is not possible to state with perfect accuracy the intervals between the principal coal beds and the most prominent datum planes because these have been found to vary considerably from point to point. It seems desirable, however, to give such average estimates as are possible for convenience of estimating the distances between the principal coal horizons. These are shown approximately in the accompanying table:

	Feet
Base of Henshaw formation to Springfield coal	1140
Geiger Lake coal to Springfield coal	1130
Limestone of Grundy Knob to Springfield coal	590
Herrin or No. 11 coal to Springfield or No. 9 coal	115
Springfield or No. 9 coal to Dekoven coal	185
Springfield or No. 9 coal to Davis or No. 6 coal	235
Springfield or No. 9 coal to Bell coal	775

LEAD AND ZINC

No deposits of lead and zine ores are known in the area, but north of Bald Knob pieces of galena and sphalerite, the common ore minerals of these metals are reported to have been found near the line of the Rough Creek fault. This area is deeply covered with loess and no rocks are exposed in the vicinity, but the occurrence of the minerals in the vicinity of known faulting is a favorable circumstance. On account of the nature of the cover, however, prospecting is very difficult and expensive, so that no great hopes may be entertained for development, and the discovery of deposits of these minerals, if such be present, will probably be entirely fortuitous.

CLAY

Brick and tile are manufactured at Henshaw and at Sturgis. Both these plants utilize the clays from the 370-foot terrace. At the former plant the clay is blue and is worked to a depth of only 3 feet. The clay pit is only a few feet above Cypress Creek and water seeps into the workings so that digging is difficult below this depth. Tile made from the blue clay alone cracks badly, but this defect is corrected by adding loess from a pit in this material a few yards away, with which the blue clay is mixed in the proportion of two parts of blue clay to one of loess. At Sturgis brick is the chief product and the clay is used without mixing. Similar clays are probably to be found at other points on the same terrace.

No tests have been made of the fire-clays underlying the coals but it is possible that some of the clays beneath the coals could advantageously be taken out while mining the coal. If the fire-clay proves to be of desirable quality, its utilization might make possible the mining of some of the thinner coals which otherwise can not be worked for many years to come.